

1. Investigators

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Co-Principal Investigator: Kuanman Xu
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2. Title of Grant

DOE OHER Project ER61968

Use of ARM Data To Develop and Test Improved Cloud Parameterizations For Use in Climate Models

3. Scientific Goals

The scientific goals of this work are: 1) To develop and test using ARM data improved parameterizations of stratiform cloud systems, including those produced through convection. 2) To employ single-column models (SCMs) and cloud system models (CSMs) in the analysis of ARM data for the purpose of evaluating parameterizations.

4. Accomplishments

- Development of a cumulus parameterization with improved cloud microphysics
- Implementation and testing of our improved stratiform cloud parameterization
- Implementation and testing of a new radiation parameterization developed by G. Stephens and colleagues
- Use of ARM data with SCMs and CSMs, and publication of several papers on the results
- Development of a new cloud-resolving model
- Use of ARM data to study the effects of downdrafts on SGP cloud systems
- Facilitation of GCSS use of ARM data
- Contributions to ARM Vision 2000

5. Progress and Accomplishments

5.1 Work with the GCM

We have developed a modified cumulus parameterization that is more fully consistent with the stratiform cloudiness parameterization. This new parameterization allows us to include such things as precipitation loading in the computation of the buoyancy force. In addition, it allows us to specify cloud-base conditions for the convective updrafts in a more physically based way. A journal article on this work has been drafted and will be submitted soon. We continue to test our new fractional cloudiness and mesoscale vertical velocity parameterization in the CSU GCM. This is a complex project with many sub-tasks. Additional prognostic variables must be added to the GCM. These must be advected in such a way that the cloud fraction remains between zero and one, and various conservation properties (e.g., conservation of total water and energy) are satisfied. Our efforts are now reaching completion. There have been no major changes in the direction of the project since its inception, because the original plan proved to be workable. We believe that this is the most advanced stratiform cloud parameterization in the world.

We are also testing a new radiation parameterization based on the work of G. Stephens and colleagues. This new scheme is more accurate, more flexible, and faster than our current scheme. By “more flexible,” we mean that the new scheme can deal with aerosols and with an arbitrary number of trace gases such as CFCs and NOX. Preliminary tests show that the new scheme has a positive impact on the realism of our climate simulations. The scheme is being used in GEWEX Cloud Systems Study (GCSS) projects and in the GCM itself. The results so far are very encouraging and we plan to submit a journal article on this work before the end of 2000.

5.2 Analysis of ARM data through use of models

We have performed numerous Single-Column Model (SCM) and Cloud System Model (CSM) simulations of various ARM Intensive Operational Periods (IOPs) conducted at the ARM Southern Great Plains (SGP) site. We have also run two cases for the SHEBA ice camp, using ECMWF data to force the SCM. We have also run TOGA COARE and GATE. Several journal articles have been published on this work (Randall and Cripe 1999; Ghan et al. 2000; Xu and Randall 1999, 2000).

5.3 A new cloud-resolving model

A new three-dimensional cloud-resolving model has been developed by M. Khairoutdinov, and applied to the simulation of ARM data. The results are being analyzed from the point of view of the second-moment equations—an approach which has never been applied to deep convection.

5.4 Effects of downdrafts on SGP cloud systems

Graduate student Daniel Lindsey is analyzing ARM data, including NEXTRAD data for the ARM SGP site, to study the effects of convective-scale downdrafts on cloud systems.

5.5 Programmatic contributions

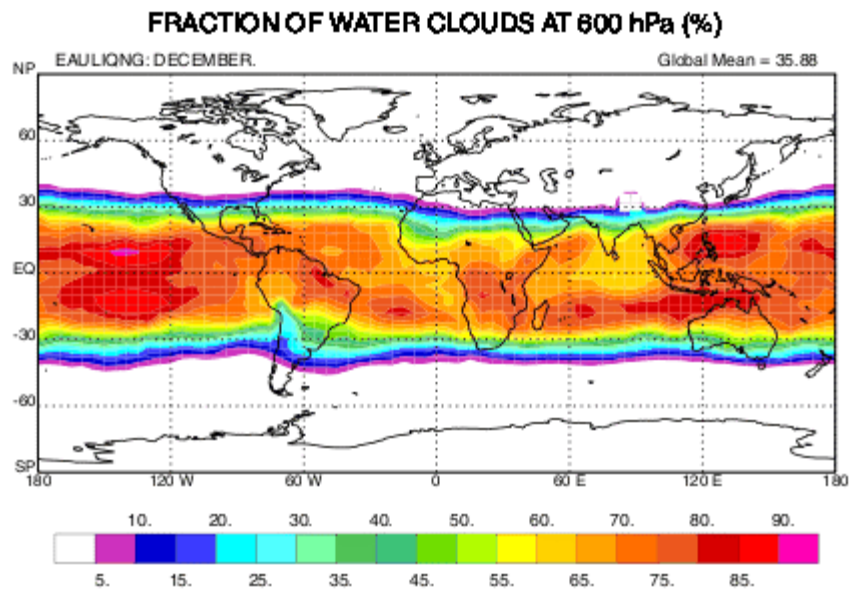
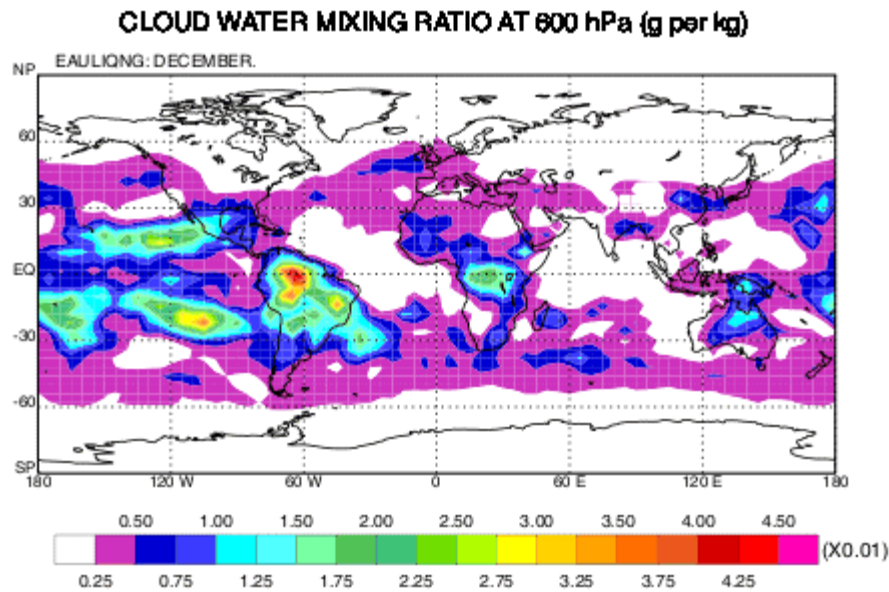
We continue to build bridges between ARM and the international GEWEX Cloud Systems Study (GCSS). At present, two different GCSS Working Groups are conducting case studies based on ARM data.

5.6 ARM Vision 2000

The P.I. took the lead in preparing a document on the current status and future of ARM, on behalf of the Cloud Parameterization and Modeling Working Group.

6. Figures

The attached figure shows a simulation of mid-tropospheric cloud water and cloud amount using our new stratiform cloud microphysics scheme.



Laura Fowler and David Randall, CSU, 2000

7. Refereed publications since 1997

Eitzen, Z., and D. A. Randall, 1999: Sensitivity of the simulated Asian summer monsoon to parameterized physical processes. *J. Geophys. Res.*, **104**, 12,177-12,191.

Fowler, L. D., and D. A. Randall, 1999: Simulation of upper-tropospheric clouds with the CSU general circulation model. *J. Geophys. Res.*, **104**, 6101-6121.

Ghan, S. J., D. A. Randall, K.-M. Xu, R. Cederwall, D. G. Cripe, J. J. Hack, S. Iacobellis, S. Klein, S. Krueger, U. Lohmann, J. Pedretti, A. Robock, L. Rotstayn, R. Somerville, G. Stenchikov, Y. Sud, G. Walker, S. Xie, J. Yio, and M. Zhang, 2000: An intercomparison of single column model simulations of summertime midlatitude continental convection. *J. Geophys. Res.*, **105**, 2091-2124.

Randall, D. A., and D. G. Cripe, 1999: Alternative methods for specification of observed forcing in single-column models and cloud system models. *J. Geophys. Res.*, **104**, 24,527-24,545.

Xu, K.-M., and D. A. Randall, 1998: Influence of large-scale advective cooling and moistening effects on the quasi-equilibrium behavior of explicitly simulated cumulus ensembles. *J. Atmos. Sci.*, **55**, 896-909.

Xu, K.-M., and D. A. Randall, 1999: A sensitivity study of radiative-convective equilibrium in the tropics with a convection-resolving model. *J. Atmos. Sci.*, **56**, 3385-3399.

Xu, K.-M., and D. A. Randall, 2000: Explicit simulation of midlatitude cumulus ensembles: Comparison with ARM data. *J. Atmos. Sci.* (in press).

8. Extended abstracts since 1997

Cripe, D. and D. A. Randall, 1997: Single column model sensitivity to initial conditions/ comparison of SCM results with ECMWF and LLNL forcing. Paper presented at the ARM/CHAMMP Meeting, San Antonio, TX, March 2-7, 1997.

Cripe, D. G., C.-L. Lappen and D. A. Randall, 1999: Simulation of Arctic weather with a single-column model. Paper presented at the 5th Conference on Polar Meteorology and Oceanography of the American Meteorological Society, Dallas, Texas, January 10-15, 1999.

DeMott, C. A. and D. A. Randall, 1997: Tropical intraseasonal oscillation characteristics from 1979-1988: A comparison of results from the CSU GCM vs. observations. Paper presented at the 22nd Conference on Hurricanes and Tropical Meteorology of the American Meteorological Society, Fort Collins, CO, May 19-23, 1997.

Fowler, L. D., and D. A. Randall, 1997: Fractional cloudiness in the CSU general circulation model. Paper presented at the IAMAS and IAPSO Joint Assembly, Melbourne, Australia, July 1-9, 1997.

Fowler, L. D., and D. A. Randall, 1997: Simulation of cirrus in the CSU general circulation model. Paper presented at the IAMAS and IAPSO Joint Assembly, Melbourne, Australia, July 1-9, 1997.

Randall, D. A., and L. D. Fowler, 1999: Eauliq: The Next Generation. Atmospheric Science Paper No. 673, Colorado State University, 65 pp.

Randall, D. A., 1997: Prescribing advection in single-column models. Paper presented at the ARM/CHAMMP Meeting, San Antonio, TX, March 2-7, 1997.

Randall, D. A., 1997: GCM Development for Climate Studies. Paper presented at the ARM/CHAMMP Meeting, San Antonio, TX, March 2-7, 1997.

Randall, D. A. and K.-M. Xu, 1997: Influence of large-scale advective cooling and moistening effects on the quasiequilibrium behavior of explicitly simulated cumulus ensembles. Paper presented at the 22nd Conference on Hurricanes and Tropical Meteorology of the American Meteorological Society, Fort Collins, CO, May 19-23, 1997.

Randall, D. A., 1997: Surface radiative forcing in climate: Observations and models. Paper presented at the IAMAS and IAPSO Joint Assembly, Melbourne, Australia, July 1-9, 1997 (Invited paper).

Randall, D. A., 1997: The role of cumulus convection in the general circulation of the atmosphere. Paper presented at the IAMAS and IAPSO Joint Assembly, Melbourne, Australia, July 1-9, 1997 (Invited paper).

Randall, D. A., 1999: A Path Towards a Next-Generation Model. Paper presented at the Workshop on the Development of Next-Generation Climate Models, Center for Climate System Research, Tokyo, Japan, March 9-11, 1999.

Xu, K.-M. and D. A. Randall, 1997: Statistical-equilibrium states of radiative-convective systems over the tropical oceans. Paper presented at the 22nd Conference on Hurricanes and Tropical Meteorology of the American Meteorological Society, Fort Collins, CO, May 19-23, 1997.

Xu, K.-M. and D. A. Randall, 1997: Cloud ensemble simulation with the ARM IOP data. Paper presented at the ARM/CHAMMP Meeting, San Antonio, TX, March 2-7, 1997.

Xu, K.-M. and D. A. Randall, 1999: Dissipation of stratiform clouds. Paper presented at the 23rd Conference on Hurricanes and Tropical Meteorology of the American Meteorological Society, Dallas, Texas, January 10-15, 1999.

9. Updated status of publications from previous report

The following three publications were listed as “submitted” or “in press” in our 1999 RIMS report. All three of them have now been accepted, and two of them have actually appeared in print.

Eitzen, Z., and D. A. Randall, 1999: Sensitivity of the simulated Asian summer monsoon to parameterized physical processes. *J. Geophys. Res.*, **104**, 12,177-12,191.

Ghan, S. J., D. A. Randall, K.-M. Xu, R. Cederwall, D. G. Cripe, J. J. Hack, S. Iacobellis, S. Klein, S. Krueger, U. Lohmann, J. Pedretti, A. Robock, L. Rotstayn, R. Somerville, G. Stenchikov, Y. Sud, G. Walker, S. Xie, J. Yio, and M. Zhang, 2000: An intercomparison of single column model simulations of summertime midlatitude continental convection. *J. Geophys. Res.*, **105**, 2091-2124.

Xu, K.-M., and D. A. Randall, 2000: Explicit simulation of midlatitude cumulus ensembles: Comparison with ARM data. *J. Atmos. Sci.* (in press).

Planned Work for the Coming Year

For the proposed one-year renewal of this project, we will complete all work on the stratiform cloud parameterization, and submit one or more papers for publication based on this work. We will also be thinking ahead to the next step in making the model more like nature.

Personnel Changes

In June 2000, Dr. Kuaman Xu left our project to take up a Civil Service position with NASA. Dr. Xu made a very strong contribution over a period of about 9 years, and will be sorely missed.